# MODEL DESCRIPTION

We used the size- and age-structured versions of Stock Synthesis 2 (SS2.EXE_v1.18 and 1.19, as of April 27, 2005) (Methot 1990, 1998, 2000) to model the population dynamics of the gopher rockfish stock. The Synthesis model projects the survival, growth and reproduction of individual age classes and incorporates ageing errors and individual variation in growth. It allows a variety of data types to be combined and used to estimate parameters in one formulation. The control file used in this assessment can be seen in Appendix B.

Initial efforts in running the model were to get the model to converge using all data elements (landings of the two fisheries, length compositions of the two fisheries, the CPFV survey CPUE index and lengths, mean weights for recreational). We assumed equal likelihood weights (= 1.0) for all data sources except for the CPFV index of abundance (= 5.0) and used a convergence criterion of 0.001 log-likelihood units for all runs of the model.

For the fisheries and survey selectivities, we started by allowing the selectivities to only fit the ascending portion of the selectivity functions and "mirrored" the selectivity of the CPFV survey to the recreational fleet. We then explored the possibility of allowing both ascending and descending portions of the selectivity function. The recreational fishery and the CPFV survey each supported a descending limb, however the model fit best once the mirror was removed and separate selectivity curves were estimated. The commercial fishery was the only one for which the model did not fit a descending limb. The baseline selectivities can be seen in Figure 14.

We did not have any studies that observed patterns of age structure to estimate (annual) natural mortality (M) or survival (S) for gopher rockfish. The oldest fish reported was 30 years old (Bloeser 1999). However, Lea et al. (1999) reported the oldest observed fish to be 24 years old in his study based on surface aging. Since there were no sample sizes associated with the 30-year-old fish, we used the 24-year-old fish to set a realistic lower bound on mortality. Based on Hoenig (1983), this corresponds with a constant mortality of approximately 0.19. Don Pearson (SWFSC, unpublished data) also aged gopher otoliths (n=100) for this assessment from two sources and found the oldest fish to be 20 years old, using the break and burn aging method. Again, based on Hoenig (1983), this corresponds with a constant mortality of approximately 0.23. Therefore, in our baseline model we set natural mortality at 0.2 and ran sensitivity analyses on M=0.15 and M=0.25.

The growth curves used in this assessment were based on the information from Lea et al. (1999), where surface aging was used. Surface aging tends to estimate fish to be younger than their true age, compared to the break and burn method. Additional gopher otoliths (n=100) from central California were available for aging (D. Pearson, SWFSC, pers. comm.), using both methods of aging. For each otolith aged, a burn to surface ratio was calculated to establish a correction factor. For each age, the average ratio was calculated and applied to each age group. Applying these correction factors increased the age of the fish at a given size. The calibrated ages were used to adjust the growth curve previously published by Lea et al. (1999). Sex information was not available with these data used for calibration, so we used a combined sex growth curve in this assessment.

We found the best-fit estimates of growth parameters of the calibrated growth equation (Figure 15) by minimizing the sum of squared deviations between the predicted and observed size at age (Hilborn and Mangel 1997), then converted from TL to FL using Equation 2. We then fit the Schnute (1981) parameterization with the asymptotic size $L_{inf}$ set to maximum observed size because of difficulties in estimating the asymptotic length. Because Synthesis uses the Schnute parameterization of the von Bertalanffy growth equation (Schnute 1981; Methot 2000), we used the parameters $t_1$=5 (years), $L_1$=22.2 (cm FL), $t_2$=15 (years), $L_2$=31.2 (cm FL) and k=0.186. We also used the error bars in the mean size at age data given in Lea et al. (1999) to estimate a coefficient of variation (CV) in size.

After initial exploratory runs, the CV of length at age was fixed at a value of 0.06 for all ages and added stability to model estimation. The first year in the model is 1965, at which time age structure is assumed to be in equilibrium with background catch levels and the average unfished level of recruitment. Strong year classes were not clearly visible in the length compositions, so the standard deviation of recruitment deviations (sigma r) is assumed to be 0.5. From 1965 to 2000, recruitments are estimated for individual years as deviations from the fitted stock-recruitment relationship. Population estimates for the 1960s and 1970s should not be considered reliable, and this aspect of the model mainly serves to provide "initial conditions" at the time of the earliest observed data in the 1980s (per recommendation by Richard Methot, NMFS). Diffuse priors were assumed for all estimated parameters.

## Baseline model and results

*Characteristics:*

- Begin model in 1965 at equilibrium catch
- Use Beverton-Holt stock-recruitment curve with fixed steepness (*h*) = 0.65
- Fix natural mortality (M) = 0.20
- Fix length at age coefficient of variation (CV) = 0.06
- Estimate recruitment for years 1965-2000
- Set CPFV survey CPUE index emphasis = 5 for baseline model (versus 1 for low scenario and 10 for high scenario)

*Effective sample sizes:*

Observed sample sizes (N fish) for the length compositions were replaced by "effective sample sizes" based on McAllister and Ianelli's (1997) description of the ratio of the variance of the expected proportion (*p*) from a multinomial distribution from sample size $N_{eff}$ to the mean squared error of the observed proportion ( $p'$ ) relative to the model's predictions (*p*), i.e., $N_{eff}$ = sum[$p(1-p)$]/sum[$(p - p')^2$]. However, this relationship is subject to statistical variability, and should hold true only on average. A log-log linear regression was used as a "smoother," and effective sample sizes used in the model were the predicted values from this regression given the year-specific observed sample size. No correction was made for the geometric mean bias associated with the log-transform.

During the exploratory phase of model development, values of effective sample size were recalculated each time a substantial change was made in model specifications, especially in specifications that have a strong effect on predicted length compositions, such as selectivity curves for individual fishery segments.

*Results and Reference Points:*

The parameter values of the baseline model are given in Table 6. The likelihood components associated with each data source used are given in Table 7.

The stock-recruitment model, a Beverton-Holt stock-recruitment relationship (SRR) was fit with steepness $h = 0.65$ (Figure 16) after evaluation and discussion with the STAR panel. Recruitment estimates are not reliable prior to the 1980s, for there was no length information prior to that time. Recruitment is estimated to be variable throughout the 1980s and 1990s; however, a decrease is seen in recruitment beginning in 1997 (Figure 17). From 2001 on, recruitment is strongly influenced by the stock-recruitment curve because of the lack of data. Figure 18 shows an increasing trend in the estimated spawning biomass since the 1980s.

Results presented in Figures 19a-c depict the fit of the baseline model to all of the compositional data of the commercial and recreational fisheries, as well as the CPFV survey. The standardized residuals are displayed annually as circles (the residual divided by the standard error of the estimated proportion). Open circles represent positive residuals, where filled circles depict negative residuals. In this figure, it can be observed where the model encountered difficulties fitting the data. Also seen in Figures 20a-c, are the standardized residuals and trends for the length frequency composition data for each fishery and survey.

The fit of the model for the CPFV survey CPUE index is shown in Figure 21. The observed and predicted seem to fit abundance trends fairly well, but the abundance index is imprecise. There appear to be inconsistencies in the early 1990s, with rather large standard errors.

The following reference points were obtained from the baseline assessment model for the northern California (north of Point Conception) gopher rockfish population.

| **Biological Reference Points** | | |
|---|---|---|
| Unfished spawning biomass ($SB_0$) | 1,995 | mtons |
| Unfished summary (age 1+) biomass ($B_0$) | 2,440 | mtons |
| Unfished recruitment (age 0) ($R_0$) | 2,758 | mtons |
| 2005 spawning biomass ($SB_{2005}$) | 1,931 | mtons |
| 2005 summary (age 1+) biomass ($B_{2005}$) | 2,385 | mtons |
| ABC ($F_{50\%} * B_{2005}$) | 246 | mtons |
| $SB_{40\%}$ (MSY proxy stock size = 0.4 * $SB_0$) | 798 | mtons |
| Exploitation rate at MSY (rockfish proxy $F_{50\%}$) | 10.3 | % |
| MSY ($F_{50\%}$ * 40% * $B_0$) | 101 | mtons |

**Uncertainties and sensitivity analyses**

**Prior STAR panel** :

All sensitivity analyses listed below were made in comparison to the baseline model prior to the STAR panel review. Even though changes were made in the final assessment model, the effect of each source would be the same. The numerical results of each sensitivity analyses are presented in Table 8 (baseline model values bolded). Unless mentioned otherwise, only one aspect of the model was changed at a time.

*Natural Mortality*:

Since we did not have any studies that observed patterns of age structure to estimate (annual) natural mortality (M) for gopher rockfish, and M strongly influences estimates of productivity and abundance, we conducted two sensitivity analyses to evaluate the effect on current biomass, relative depletion, exploitation rate and the allowable biological catch (ABC). The value of M=0.20 was used in the baseline model, based on Hoenig (1983), as previously discussed. As seen in Table 8, current biomass, relative depletion, exploitation rate and the ABC decreases with M=0.15 and increases with M=0.25 for all cases.

*Coefficient of Variation (CV) on Growth*:

After allowing the CV to be freely estimated in initial runs of the model, we eventually fixed this value at 0.06 for growth. To test the sensitivity of this parameter on the results, we also evaluated the CV at 0.04 and 0.08. There appears to be little, if any, change in the outcome for current biomass, relative depletion, exploitation rate or the ABC (Table 8), especially for a CV=0.08. Neither alteration improved the fit of the model.

*Commercial landings*:

Due to the uncertainty of commercial landings being reported under market categories in general and the decrease in commercial landings in the mid-1980s when the “group gopher” market category appeared, we adjusted the estimates for 1984-1988, based on species compositions from CALCOM to “reconstruct” commercial landings throughout the time period. There were no differences in the outcome for current biomass, relative depletion, exploitation rate or the ABC (Table 8) when compared to the baseline model.

*Ricker model*:

To investigate the outcome of the Ricker curve, we let unfished recruitment ($R_0$) be estimated, giving an initial ln($R_0$) value of 7.2, instead of the estimated 7.7 in the Beverton-Holt curve. Overall, the Ricker model gave a slightly better fit to the model (1154.10) compared to the Beverton-Holt (1155.17). This sensitivity analysis results in no change of the relative depletion or the exploitation rate; however, there was a significant effect (decrease) in the estimated current biomass and ABC (Table 8).

*Emphasis on data sources*:

We also conducted a series of runs to investigate the effect of the emphasis for each likelihood component in the baseline model. We set the emphasis at 0.1 and 10 for each component and the results are shown in Table 9. (Note: The emphases presented here were run with version 1.18, prior to all other results presented in this assessment.)

**Post-STAR panel:**

*Emphasis on the CPFV survey CPUE index*:

The major area of uncertainty the STAR Panel and STAT agreed upon was the bounding scenarios of the baseline model using the CPFV survey CPUE index for a measure of relative abundance, which brings into question the accuracy of abundance trends derived from this series of information. The emphasis on this data source (with associated relative probabilities in parenthesis) was set at 1 (0.22), 5 (0.40) and 10 (0.38), with 5 being the most likely scenario and used in the baseline model. To show this uncertainty, we present the resulting estimates of spawning biomass in Figure 22. (Note: An error in calculation of the CPFV survey CPUE index was discovered during final document preparation. The consequences of this error are explored in Appendix C.)

## STATUS OF THE STOCK AND PROJECTIONS

Considering the results of the baseline model, Table 10 shows the stock projections for the northern California gopher rockfish population, depending on the emphasis used on the CPFV survey CPUE survey (with 5 being most likely and used in the baseline model). The PFMC's harvest policy for rockfish (ABC based on $F_{50\%}$ harvest rate) was used to forecast harvest in the next 12 years (to the year 2016) and a 40:10 precautionary adjustment did not need to be made. Forecasts were based on an allocation between the commercial and recreational fisheries, 26 and 54 metric tons, respectively. GMT members made this recommendation of using the 5-year average take from 2000-2004 for the commercial fishery and the average take in 2002 and 2004 for the recreational fishery to use in these projections. In this assessment, gopher rockfish, in any scenario, do not appear to be below target levels and the stock appears to be healthy.